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## **An Evaluation of the Burn-Through Resistance of Cargo Lining Materials**

Dave Blake

DOT/FAA/CT-TN85/11

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16. Abstract Sixty-four fire tests were conducted to evaluate the burnthrough resistance of cargo lining materials. The tests subjected a cargo liner to an intense flame created by a two-gallon-per-hour kerosene burner, using a new test method that was proposed in Notice of Proposed Rule Making (NPRM) 84-11 to replace the Bunsen burner test. The tests were conducted with the samples mounted both vertically and horizontally. The criteria for passing the test, as stated in NPRM 84-11, is that (1) no flame may penetrate the liner and (2) the temperature four inches above the horizontal sample must not exceed 400 degrees Fahrenheit (° F). The majority of the liners tested are currently in service; the remaining samples were advanced materials or blends that have been proposed as cargo liners. Many of the liners did not pass this test. The majority of the liners that failed did so because the temperature above the liner exceeded 400° F even though burnthrough did not occur in most cases.					
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## TABLE OF CONTENTS

	Page
EXECUTIVE SUMMARY	v
INTRODUCTION	1
Purpose	1
Background	1
Test Configuration	2
Results	2
REFERENCES	2
APPENDIX	
A — Two-Gallon/Hour Burner Specifications	

## LIST OF ILLUSTRATIONS

Figure		Page
1	Position of Test Specimen	3
2	Thermocouple Rake Bracket	4
3	Calorimeter Bracket	5

## LIST OF TABLES

Table		Page
1	Description of Test (5 pages)	6
2	Highest Temperature Measured Above Horizontal Sample (Test 1 through 8)	11
3	Highest Temperature Measured Above Horizontal Sample (Test 9 through 18)	12
4	Highest Temperature Measured Above Horizontal Sample (Test 19 through 28)	13
5	Highest Temperature Measured Above Horizontal Sample (Test 29 through 38)	14
6	Highest Temperature Measured Above Horizontal Sample (Test 39 through 44)	15

## EXECUTIVE SUMMARY

This report contains the results of fire tests performed on cargo compartment lining material. The study was an outgrowth of previous work involving full-scale fire tests in class D and class C cargo compartments as well as small-scale fire tests. The previous full-scale tests concluded that the Bunsen burner test specified in FAR 25.855 does not ensure that cargo liners will not burn through when subjected to realistic fire exposure conditions. Once a liner burnthrough occurs, the fire containment or suppression capability of the cargo compartment is reduced. The tests conducted in this report utilized a new, more severe test method, proposed in Notice of Proposed Rule Making (NPRM) 84-11 to replace the Bunsen burner tests currently used to evaluate the burn-through resistance of cargo liners. The criteria for passing the test, as stated in NPRM 84-11, is that (1) no flame may penetrate the liner and (2) the temperature, four inches above the horizontal sample, must not exceed 400 degrees Fahrenheit (°F). The majority of the liners tested in this study are currently in use in cargo compartments, the remaining samples were advanced materials or blends that have been proposed as cargo liners. Many of the liners that were tested did not pass this new test. The majority of the liners that failed did so because the temperature above the liner exceeded the 400° F temperature criteria, even though burnthrough did not occur in most cases.





## INTRODUCTION

### PURPOSE.

The purpose of this report is to present the results of the evaluation of the burn-through resistance of cargo compartment lining materials when subjected to realistic severe fire exposure conditions.

### BACKGROUND.

This study was an outgrowth of previous cargo compartment work involving full-scale class D cargo and class C cargo compartment fire tests and small-scale fire tests (references 1 and 2).

The majority of lower cargo compartments on commercial air transports are certified as class D or class C compartments. Class D compartments are generally smaller than class C and are not required to have smoke detection or fire suppression systems. Instead, they depend on the limited availability of fresh air in the compartment to eventually suppress, through oxygen starvation, any fire that is likely to occur. The integrity of liners used in class D compartments is crucial because a burnthrough would allow the entrainment of cabin exhaust air which flows around the compartment. This would feed oxygen to the fire and seriously limit the fire containment capabilities of the compartment.

Class C cargo compartments are generally larger than class D compartments and are often used for containerized cargo. They are required to have smoke detection and fire suppression systems as well as the ability to control ventilation into the compartment. Some of these compartments have forced hot air heating systems and/or forced ventilation systems to control the environment in the compartment. The fire suppression systems typically use Halon 1301 as the agent. The quantity of agent in the initial discharge is calculated to provide a concentration of 5 percent in any empty compartment. A backup bottle of Halon 1301 is also available and is used to keep the agent concentration above 3 percent for at least 1 hour. The integrity of the liners in class C compartments is important because a burnthrough would allow cabin exhaust air to mix with the air in the cargo compartment. This would not only provide fresh air to a fire but would also dilute the concentration of suppression agent in the compartment.

The class D cargo compartment work concluded that Bunsen burner tests specified in FAR 25.853 and FAR 25.855 did not assure that the liners used in class D cargo compartments will not burn through when subjected to realistic fires (reference 1). As a result of that work, a more severe test method was proposed for class D cargo liners (reference 2). This was the test method used to evaluate the liners discussed in this report. The test utilized a 2-gallon per hour kerosene burner and approximated the peak temperatures and heat flux levels measured in the full-scale tests of class D cargo compartments.

One of the conclusions of the class C cargo project was similar to the one reached from the class D project, i.e., the burn test specified in FAR 25.855 does not assure that the cargo liners will not burn through when subjected to realistic fire exposure conditions. Based on that conclusion it was recommended that the kerosene burner test proposed for class D liners be used for class C liners also.

## TEST CONFIGURATION.

The burner used in this evaluation was obtained from the Park Oil Burner Manufacturing Company of Atlantic City, New Jersey. The temperature and heat flux outputs of the burner were similar to those of the Lennox burner which is an industry standard used to evaluate the fire resistance of flexible hose assemblies. The specifications for the burner are listed in appendix A. The burner was mounted vertically in the test stand in such a way as to expose the horizontal sample (simulated ceiling liner) to direct flame impingement and the vertical sample (simulated sidewall liner) to less severe fire exposure conditions. Figure 1 illustrates the position of the test specimens relative to the burner and the pertinent dimensions of the test fixture. The burner was calibrated to produce at least 8.0 Btu/ft<sup>2</sup>-sec and 1700 degrees Fahrenheit (° F) at a distance of 8 inches above the burner cone. This was the distance at which the horizontal sample was mounted. Figures 2 and 3 illustrate the positions of the thermocouples and heat flux transducer used to calibrate the burner.

## RESULTS.

Table 1 contains the results of the tests of cargo lining materials. Listed in the table is a brief description of the materials tested and the highest temperature measured by the thermocouple located 4 inches above the horizontal sample. The majority of the liners that were tested are currently in service; the remaining samples were advanced materials or blends that have been proposed as cargo liners. Tables 2 through 6 illustrate the highest temperature measured by the thermocouple for all test. Using 400 degrees as the pass/fail criteria, 20 of the 46 materials tested would pass. Using 500° F as the criteria, 32 of the 46 materials would pass.

With 600° F as the criteria, 34 of the 46 materials would pass. The materials that would pass a 600° F pass/fail criteria include all the fiberglass liners tested, with the exception of one sample of unidirectional fiberglass with epoxy resin. The proposed test method using the kerosene burner produces realistic fire exposure conditions and is an effective test to evaluate the burn-through resistance of cargo lining material.

## REFERENCES

1. Blake, D. R. and Hill, R. G., Fire Containment Characteristics of Aircraft Class D Cargo Compartments, FAA/CT-82/156, 1983.
2. Brown, L. J. and Cole, C. R., A Laboratory Test for Evaluating the Fire Containment Characteristics of Aircraft Class D Cargo Compartment Lining Material, DOT/FAA/CT-83/44, 1983.

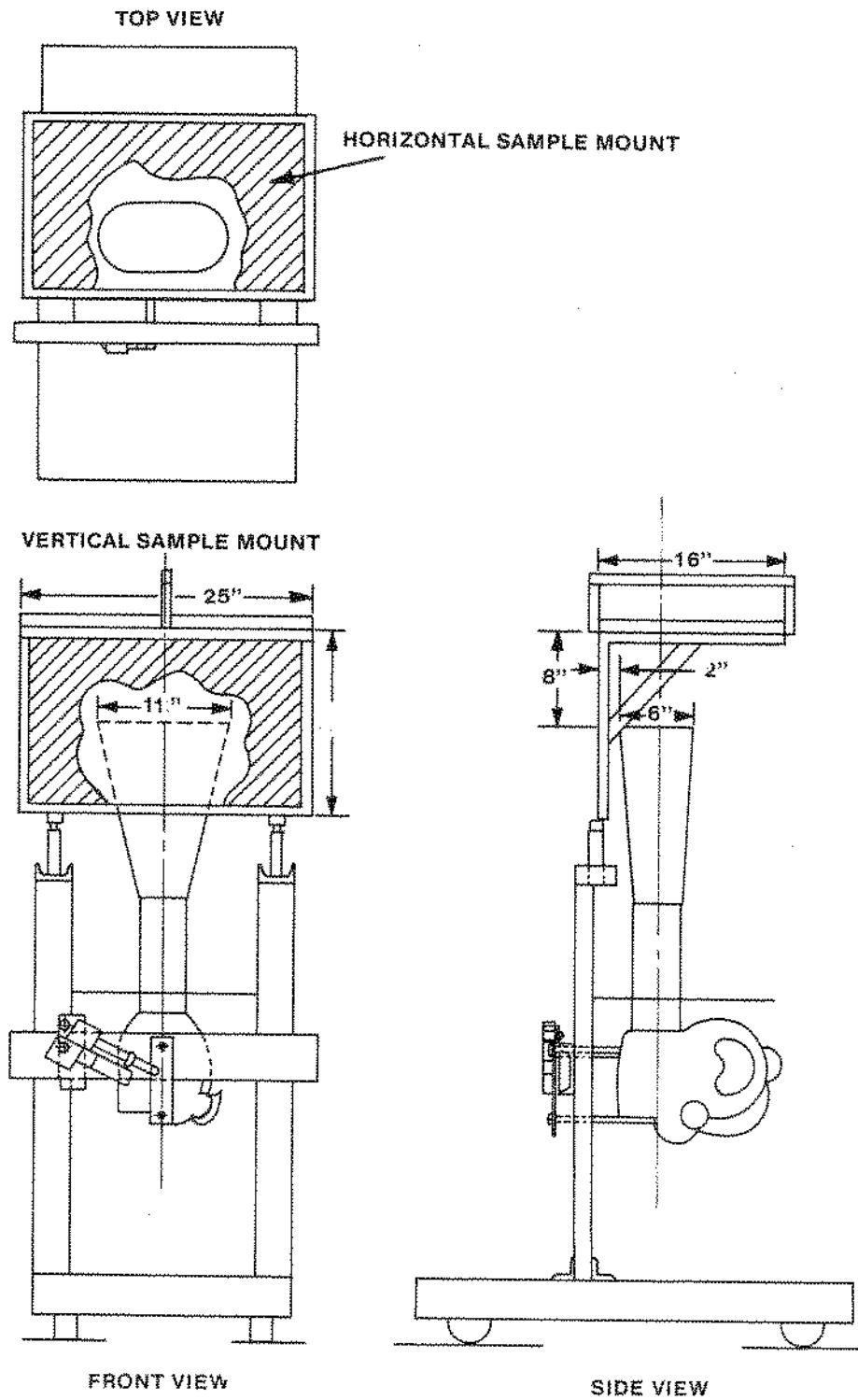
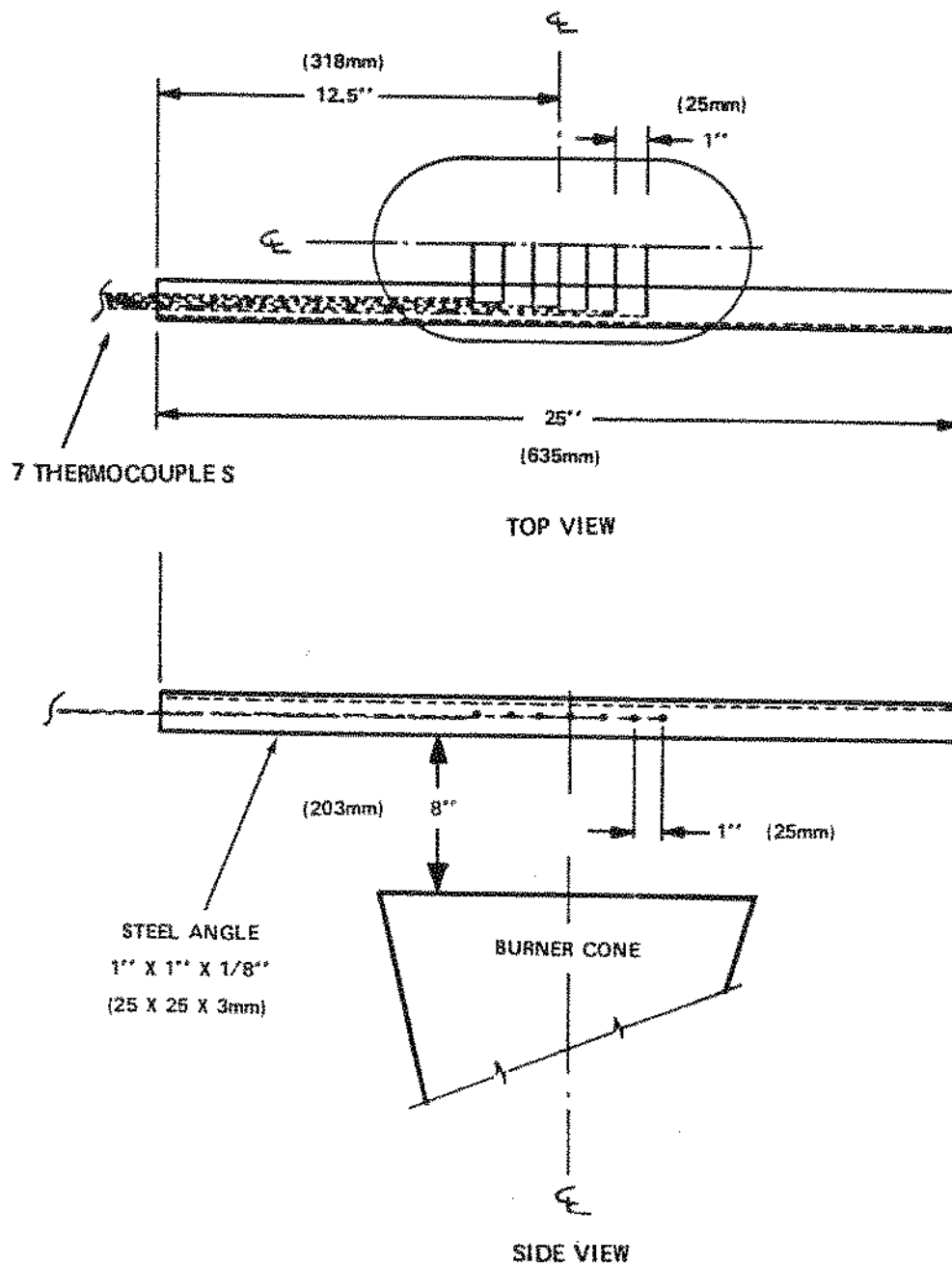


FIGURE 1. POSITION OF TEST SPECIMEN

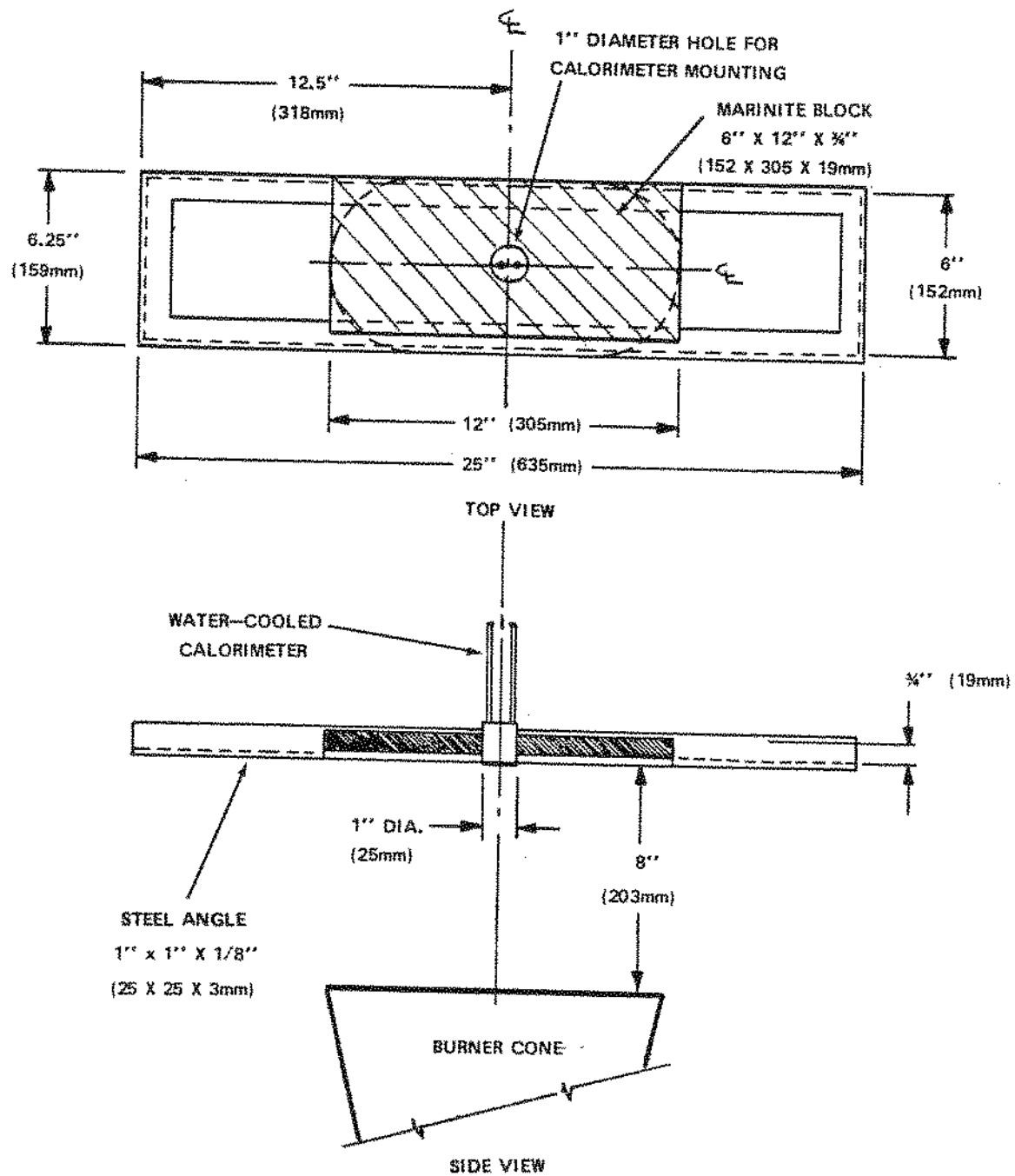


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THERMOCOUPLE RAKE BRACKET

NOTE: BRACKET WAS CLAMPED TO TEST STAND. THERMOCOUPLES CENTERED OVER BURNER CONE.

FIGURE 2. THERMOCOUPLE RAKE BRACKET



NOTE: BRACKET WAS CLAMPED TO TEST STAND, CALORIMETER CENTERED OVER BURNER CONE.

83-44

FIGURE 3. CALORIMETER BRACKET

TABLE 1. DESCRIPTION OF TEST

1. TOP:FG/POLYESTER BMS 8-2 CLASS 2 GRADE B TYPE II  
TEDLAR BOTH SIDES  
SIDE:SAME  
RUN 1 - 360 DEG F.  
RUN 2 - 325  
RUN 3 - 350
2. TOP:NEOPRENE/FG 1 PLY B.F. GOODRICH FS-844  
SIDE:SAME  
RUN 1 - 409 DEG F.  
RUN 2 - 418  
RUN 3 - 417
- 2A. TOP:NEOPRENE/FG 2 PLY B.F. GOODRICH FS-844  
SIDE:SAME  
RUN 1 - 385 DEG F.  
RUN 2 - 408  
RUN 3 - 386
3. TOP:FG/EPOXY BMS 8-100 TYPE 50 CLASS 2 50 MIL  
SIDE:SAME  
RUN 1 - 330 DEG F.  
RUN 2 - 1007 BURNED THRU
4. TOP:FG BMS 8-100 TYPE 20 CLASS 2 20 MIL  
SIDE:SAME  
RUN 1 - 556 DEG F.
5. TOP:UNIDIRECTIONAL FG/PHENOLIC BMS 8-223  
CLASS 1 GRADE B TYPE 20  
SIDE:SAME  
RUN 1 - 372 DEG F.  
RUN 2 - 439  
RUN 3 - 441
6. TOP:FG BMS 8-2 TYPE A31RG4W  
SIDE:SAME  
RUN 1 - 499 DEG F.  
RUN 2 - 560
7. TOP: BMS 8-2D CLASS 2 GRADE B TYPE 20 M.C. GILL.  
SIDE:BMS 4-17 TY2 CL1 GR2 FLOOR PANEL USED AS ENDWALL  
RUN 1 - 419 DEG F.  
RUN 2 - 397

TABLE 1. DESCRIPTION OF TEST (Continued)

- 7A. TOP: BMS 8-2D CLASS 2 GRADE B TYPE 20 M.C. GILL  
SIDE: BMS 4-17 TY4 CL1 GR2 FLOOR PANEL USED AS ENDWALL  
RUN 1 - 411 DEG F.
8. TOP: CONOLITE BMS 8-2 CLASS 2 GRADE B TYPE 13 MF404  
SIDE: FG/KEVLAR/GRAPHITE 0.50 INCH HONEYCOMB PANEL  
RUN 1 - 420 DEG F. BURNER OUT OF FUEL AT 4:15  
RUN 2 - 405
9. TOP: BMS 8-2 CLASS 2 GRADE B TYPE 30 GILLINER 1366 T-30  
LOT M2370 8/2/84  
SIDE: SAME  
RUN 1 - 327 DEG F.  
RUN 2 - 320  
RUN 3 - 346
10. TOP: BM3 4-17 TY2 NOMEX/EPOXY FLOOR PANEL USED AS ENDWALL  
SIDE: SAME  
RUN 1 - 411 DEG F.
11. TOP: BMS 8-2D CLASS 2 GRADE B TYPE 20 M.C. GILL  
SIDE: FG/KEVLAR/GRAPHITE 0.50 INCH HONEYCOMB PANEL  
RUN 1 - 613 DEG F.
12. TOP: BMS 8-2A 13 MIL CONOLITE FG USED IN DC-10 TESTS  
SIDE: SAME  
RUN 1 - 436 DEG F.
13. TOP: FG BMS 8-2D CLASS 2 GRADE B TYPE 20 M.C. GILL  
SIDE: SAME  
RUN 1 - 360 DEG F.
14. TOP: FG GILLFAB 1100W (.023")  
SIDE: FG GILLINER 1066 (.045")  
RUN 1 - 335 DEG F.
15. TOP: FG GILLFAB 1100W (.030")  
SIDE: FG GILLFAB 1100W (.045")  
RUN 1 - 290 DEG F.

TABLE 1. DESCRIPTION OF TEST (Continued)

16. TOP: FG GILLINER 1066 (.016")  
SIDE: FG GILLINER 1066 (.030")  
RUN 1 - 326 DEG F.
17. TOP: HARD KAOWOOL BOARD  
SIDE: KEVLAR/FG/EPOXY 1 LAYER GLASS (.076")  
RUN 1 - 150 DEG F.
18. TOP: HARD KAOWOOL BOARD  
SIDE: KEVLAR/FG/EPOXY 2 LAYER GLASS (.076")  
RUN 1 - 150 DEG F.
19. TOP: WOVEN F/G GILLINER 1366 BMS 8-2D 30 MIL  
SIDE: SAME  
RUN 1 - 240 DEG F.
20. TOP: WOVEN F/G GILLINER 1366 BMS 8-2D TYPE 2 11 MIL  
SIDE: SAME MFG. 4/19/83  
RUN 1 - 261 DEG F.
21. TOP: 20 MIL DC-10 NON-WOVEN F/G W/ "GILLPATCH"  
SIDE: SAME ONLY WITHOUT "GILLPATCH"  
RUN 1 - 630 DEG F.
22. TOP: NON-WOVEN FG W/TEDLAR FACING 30 MIL  
SIDE: SAME  
RUN 1 - 440 DEG F.
23. TOP: KEVLAR/FG/EPOXY 2 LAYER GLASS FACE (.076")  
SIDE: SAME  
RUN 1 - 320 DEG F.
24. TOP: KEVLAR/FG/EPOXY 1 LAYER GLASS FACE (.076") BAFFLED  
SIDE: SAME  
RUN 1 - 401 DEG F.
25. TOP: NON-WOVEN F/G WITH TEDLAR BMS 8-100E 30 MIL BAFFLED  
SIDE: SAME  
RUN 1 - 305 DEG F.



TABLE 1. DESCRIPTION OF TEST (Continued)

26. TOP: BMS 8-2A 13 MIL CONOLITE WITH PATCH WITH F/G TAPE  
BAFFLED  
SIDE: BMS 8-2A 13 MIL CONOLITE NO PATCH  
RUN 1 - 408 DEG F.
  
27. TOP: BMS 8-2A 13 MIL CONOLITE BAFFLED  
SIDE: BMS 8-2A 13 MIL CONOLITE WITH PATCH WITH F/G TAPE  
RUN 1 - 310 DEG F.
  
28. TOP: BMS 8-2A 13 MIL CONOLITE WITH PATCH WITH DUCT TAPE  
BAFFLED  
SIDE: BMS 8-2A 13 MIL CONOLITE NO PATCH  
RUN 1 - 453 DEG F.
  
29. TOP: BMS 8-2A 13 MIL CONOLITE BAFFLED  
SIDE: BMS 8-2A 13 MIL CONOLITE WITH PATCH WITH DUCT TAPE  
RUN 1 - 378 DEG F.
  
30. TOP: GILLFAB 1100W 23 MIL WOVEN F/G  
SIDE: SAME  
RUN 1 - 221 DEG F.
  
31. TOP: GILLFAB 1100W 30 MIL WOVEN F/G  
SIDE: SAME  
RUN 1 - 230 DEG F.  
RUN 2 - 340  
RUN 3 - 228
  
32. TOP: KEVLAR/FG BLEND PHENOLIC RESIN 32 MIL  
SIDE: SAME  
RUN 1 - 617 DEG F.
  
33. TOP: KEVLAR/FG BLEND PHENOLIC RESIN 22 MIL  
SIDE: SAME  
RUN 1 - 785 DEG F. BURN THROUGH
  
34. TOP: KEVLAR/PHENOLIC 21 MIL  
SIDE: SAME  
RUN 1 - 900+ DEG F. BURN THROUGH

TABLE 1. DESCRIPTION OF TEST (Continued)

35. TOP: WOVEN FG/PHENOLIC 21 MIL  
SIDE: SAME  
RUN 1 - 352 DEG F.
36. TOP: WOVEN FG GILLINER 1366 11 MIL  
SIDE: SAME  
RUN 1 - 275 DEG F.
37. TOP: KEVLAR-GRAPHITE 26 MIL  
SIDE: SAME  
RUN 1 - 950 DEG F. BURN THRU
38. TOP: KEVLAR-GRAPHITE 26 MIL  
SIDE: SAME  
RUN 1 - 1200 DEG F. BURN THRU
39. TOP: KEVLAR/S-GLASS W/ TEDLAR FACE 15 MIL  
SIDE: SAME  
RUN 1 - 741 DEG F.
40. TOP: 11 MIL KEVLAR/EPOXY W/TEDLAR FACE  
SIDE: SAME  
RUN 1 - 1200+ DEG F. BURN THRU 10 SEC.
41. TOP: 17 MIL KEVLAR/EPOXY W/TEDLAR FACE  
SIDE: 27 MIL KEVLAR/EPOXY W/TEDLAR FACE  
RUN 1 - 1200+ DEG F. BURN THRU 10 SEC.
42. TOP: HARD KAOWOOL BOARD  
SIDE: 5052 ALUM 63 MIL ALCOA  
RUN 1 - 135 DEG F.
43. TOP: HARD KAOWOOL BOARD  
SIDE: 2024 ALCLAD ALUM 25 MIL KAISER  
RUN 1 - 170 DEG F.  
RUN 2 - 223 BURN THRU SIDEWALL
44. TOP: HARD KAOWOOL BOARD  
SIDE: 2024 ALCOA 50 MIL ALUM  
RUN 1 - 161 DEG F.  
RUN 2 - 165

TABLE 2. HIGHEST TEMPERATURE MEASURED ABOVE HORIZONTAL SAMPLE (TEST 1 THROUGH 8)

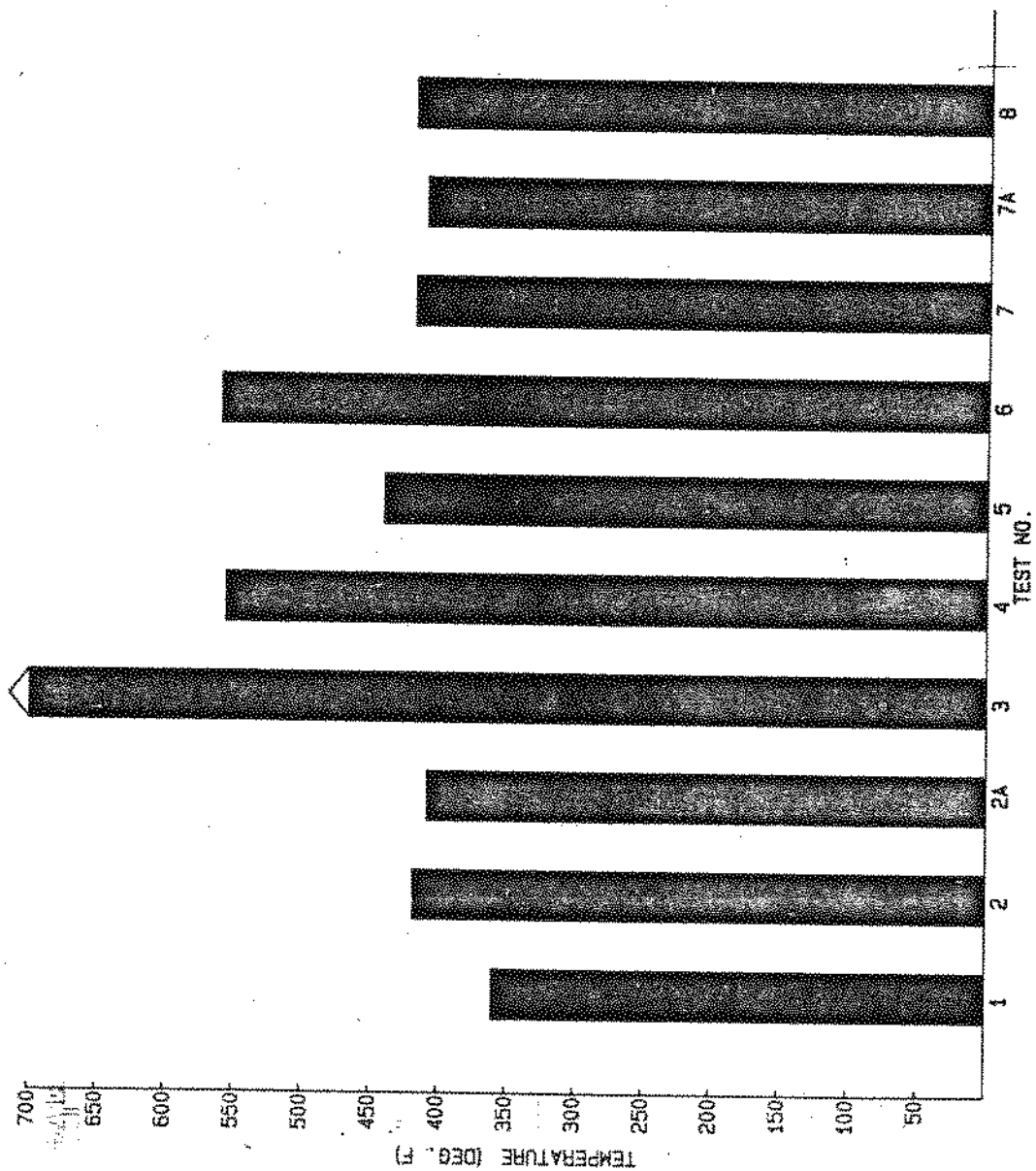


TABLE 3. HIGHEST TEMPERATURE MEASURED ABOVE HORIZONTAL SAMPLE (TEST 9 THROUGH 18)

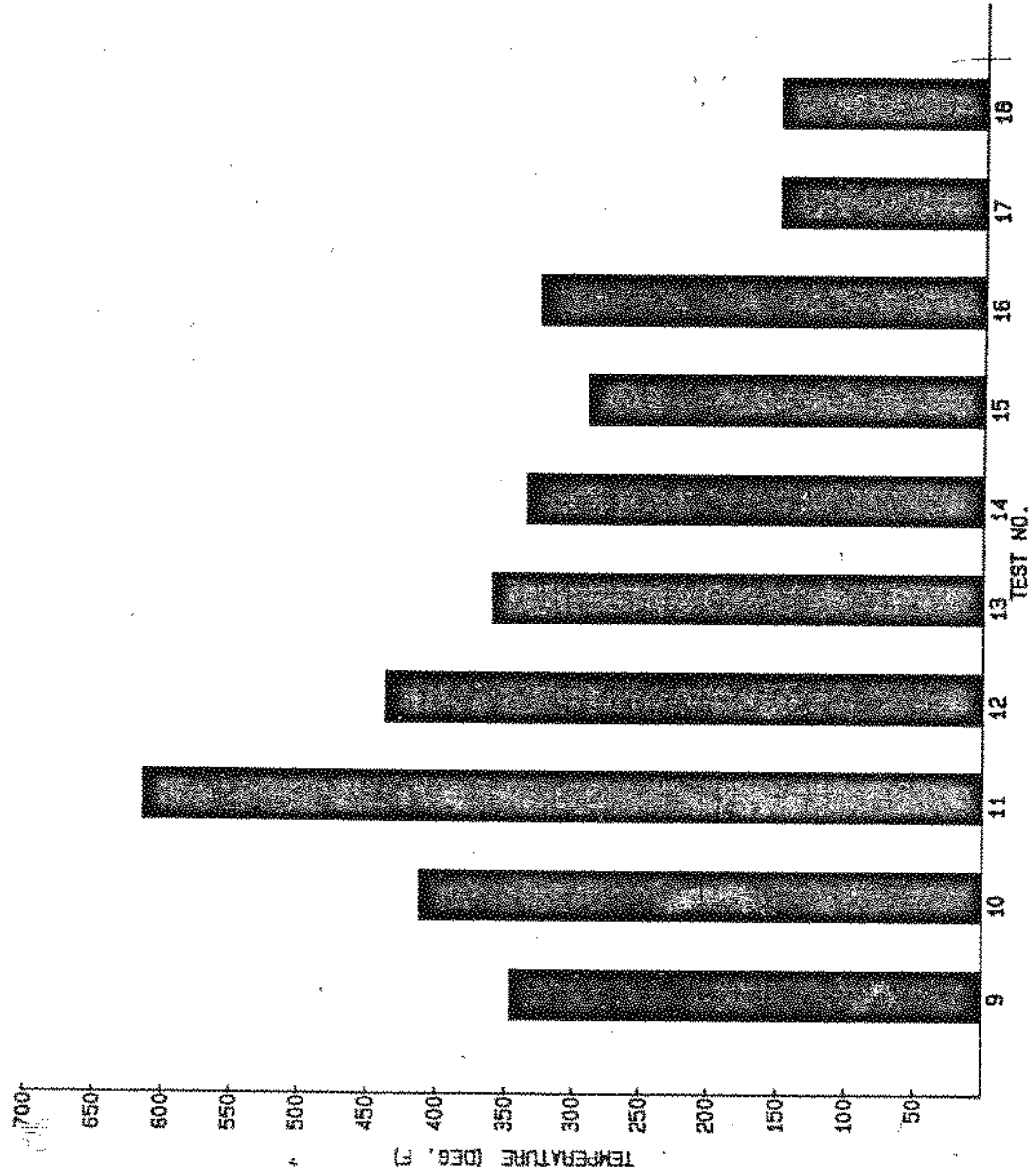


TABLE 4. HIGHEST TEMPERATURE MEASURED ABOVE HORIZONTAL SAMPLE (TEST 19 THROUGH 28)

△ - TEMP > 700

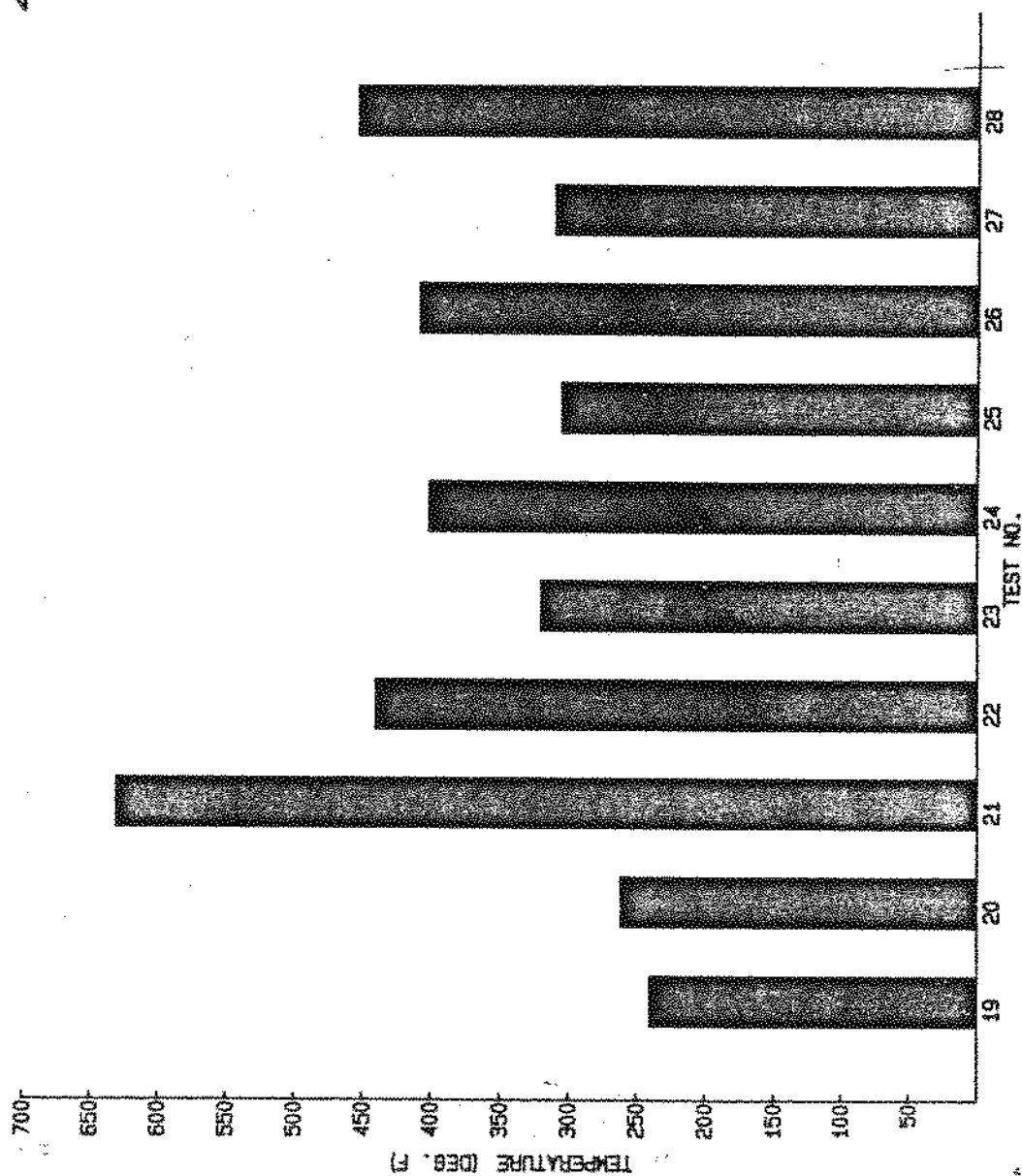


TABLE 5. HIGHEST TEMPERATURE MEASURED ABOVE HORIZONTAL SAMPLE (TEST 29 THROUGH 38)

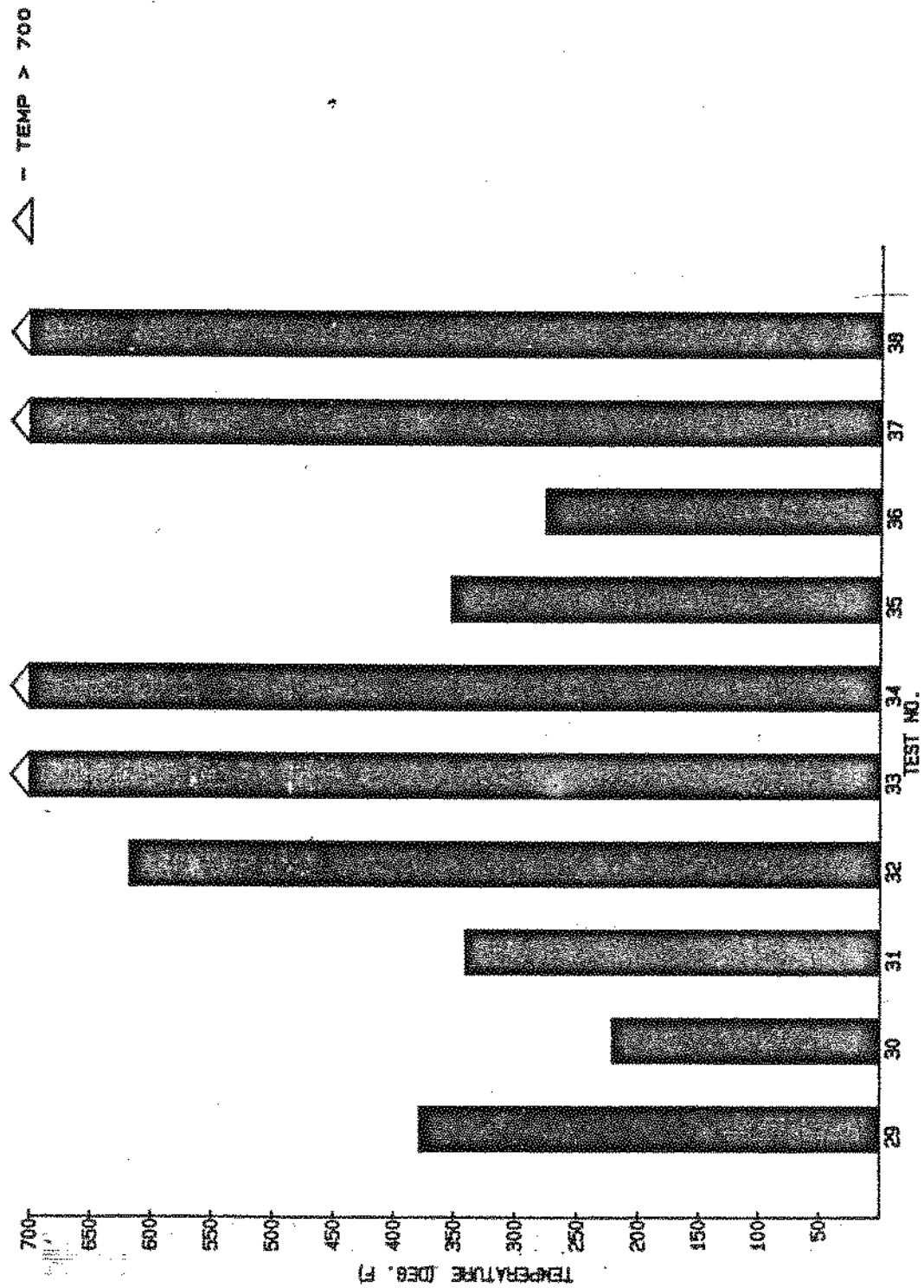
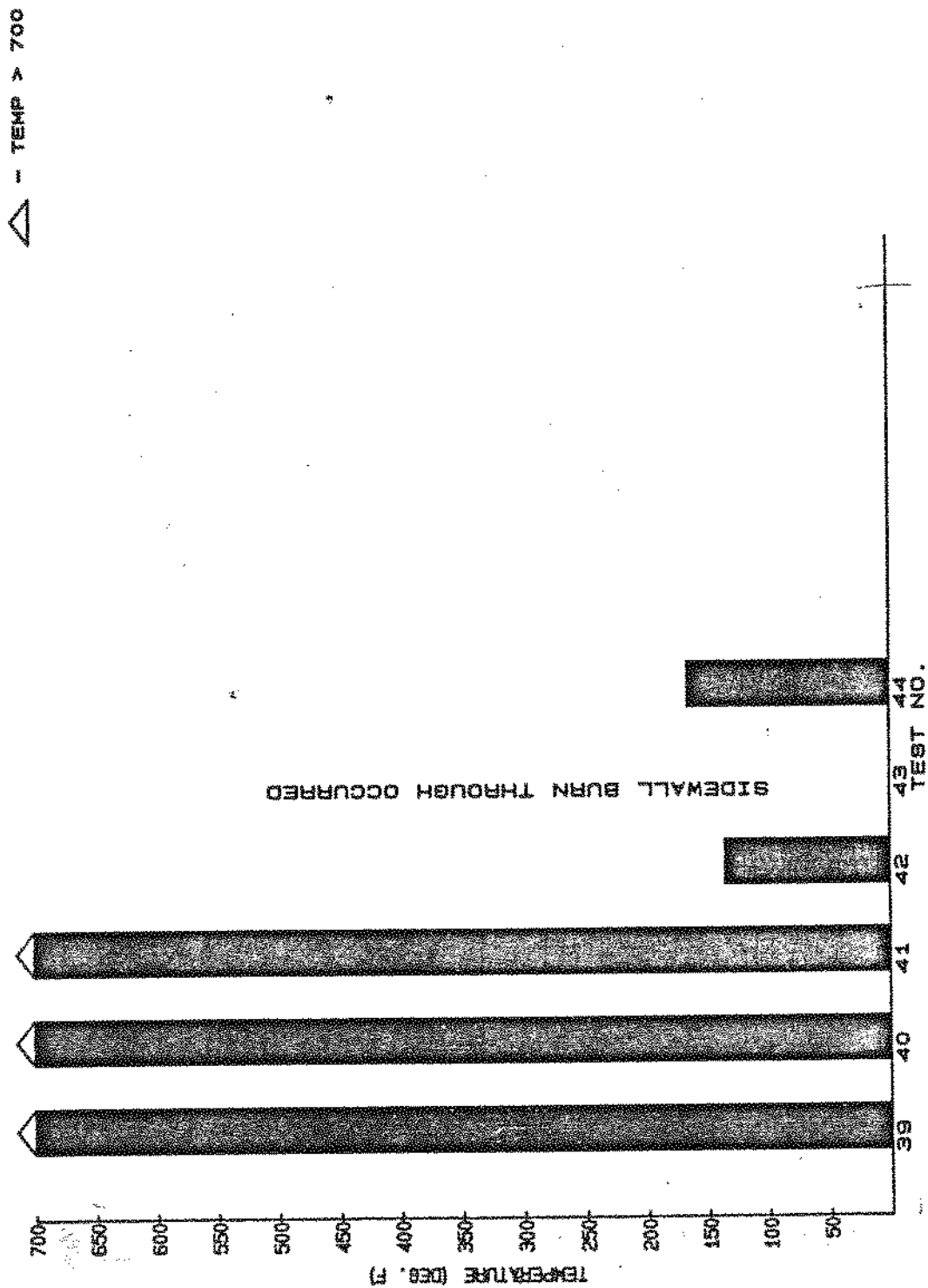


TABLE 6. HIGHEST TEMPERATURE MEASURED ABOVE HORIZONTAL SAMPLE (TEST 39 THROUGH 44)







## APPENDIX A

### 2-GALLON/HOUR BURNER SPECIFICATIONS

Fuel Flow - 2.0 Gallon-per-hour

Motor - 1/4 H.P. 3450 RPM

Blower Wheel - 3.5 x 5.25 inches

Pump - Single Stage

Tube Extension - 4.125 x 11 inches

The Park Oil Burner used in this study contains a 2.25 gallon-per-hour 80-degree nozzle operated at a pressure of 85 psig, delivering 2.03 gallons-per-hour. Air pressure in the air tube, or burner tube, was adjusted to produce 0.17 inches of water.

The Park Oil Burner is a suitable replacement for the Lennox Burner and can be obtained from the following address:

Park Oil Burner Mfg. Company  
N. New York Ave. Absecon BLvd.  
Atlantic City, New Jersey 08401  
Phone: (609)-344-7709

